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National Cases combining promotion scheme, ownership structure and operational strategy for Denmark, France and Portugal

Work package 6

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National Cases combining promotion scheme, ownership structure and operational strategy for Denmark, France and Portugal

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Acronyms

PESTLE	Political, Economical, Social, Technological, Legislative, Environmental
SWOT	Strengths, Weaknesses, Opportunities and Threats
FC	Fuel Cell
mCHP	Micro-Combined Heat and Power
CHP	Combined Heat and Power
R&D	Research and Development
EC	European Commission
EU	European Union
WP	Work Package
FC mCHP	Fuel cell based Micro-Combined Heat and Power
VPP	Virtual Power Plant
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IMF	International Monetary Fund
OMIP	Iberian energy market
IEA	International Energy Agency
FIT	Feed in tariff
SETplan	European Commission Strategy Energy Technology plan
NOx	Nitrogen oxide
SOx	Sulfur oxide
CO	Carbon monoxide
OECD	Organization for Economic Co-operation and Development
PACo	French technological network on fuel cells
APREN	Portuguese Renewable Energy Association

Foreword

The scope of the FC4Home project is to assess technical and economic aspects of the ongoing fuel cell based micro-combined heat and power demonstration projects by addressing the socio-economic and systems analyses perspectives of a large-scale promotion scheme of fuel cells. This was carried out by means of energy systems analysis and studies on central cases for each of the participating project partners.

This document comprises results from Work Package 6 – National Cases combining support schemes, ownership structures and operational strategies of the FC4Home research project (http://fc4home.com/). It integrates insights from Work Package 1 – Support schemes and ownership structures – the policy context for fuel cell based micro-combined heat and power, Work Package 2 – Residential fuel cell micro CHP in Denmark, France and Portugal – potential development, ownership models and support schemes, Work Package 4 – Analyses of models for promotion schemes and ownership arrangements and Work Package 5 – Residential fuel cell micro CHP in Denmark, France and Portugal – model description, accomplished during the project.

Objectives of FC4Home project:

The main objectives of FC4Home project are:

- State the socio-economic consequences of different promotion schemes and ownership conditions.
- Analyze the current national regulatory frameworks and policy conditions in each country within the project.
- Perform energy system analyses of fuel cell based micro combined heat and power systems as a function of the chosen operational strategies including the economic and environmental consequences.
- Different combinations of promotion schemes and ownership arrangements form different incentive-structures. Utilizing a partial-equilibrium model and structural analysis methods this WP handles quantitative and qualitative analyses addressing key economic criteria, among these an efficient deployment of fuel cells.
- Outline stakeholder interests as well as potential impacts and consequences.
- Disseminate the results of the project to relevant stakeholders.

Project Partners:

- Risø National Laboratory for Sustainable Energy, Technical University of Denmark (Denmark)
- EDF / EIFER (France)
- Simbiente – Environmental Engineering and Management (Portugal)

Acknowledgement

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Executive Summary

With the increasing challenges of climate change, depletion of fossil fuel resources and population growth, the search for cleaner and more efficient energy sources and technologies is becoming essential.

Fuel cell based mCHP is one alternative technology with significant future potential. After a slow start caused by the early stage of technology development and consequently by the initial high costs of fuel cell hardware, the world market of fuel cell is showing now a consistent growth rate in several regions in Europe, Asia and the United States.[(4)]

The main objective of this report was to identify and organize key aspects related to the introduction of residential fuel cell based mCHP on the energy market in the three European countries (Denmark, France and Portugal) involved in the FC4Home project, and based on the analysis of the data through PESTLE and SWOT frameworks, giving insights about the current situation and future prospects of the technology within the geographical context of the work.

Results of the analysis were organized based on PESTLE framework. Results show that support from local government and funding programs are strong drivers, while strategy and policy development in a European context drive decisions at different places within the analyzed countries. On the other side, current European financial crisis together with the high process of fuels play a mixed role in determining the rate at which FC mCHP is being developing in the different countries. Cost of the technology is seen as a negative impact that will reduce significance in time, also when considered together with the business model adopted at local level for the financing of implementation. Maturity of the technology and available information for the public audience are considered as the main relevant aspects when analyzed social impacts of the FC mCHP. Environmental goals are also a main factor being considered by all stakeholders in the FC mCHP landscape.

1. Context and Objectives

With the increasing challenges of climate change, depletion of fossil fuel resources and population growth, the search for cleaner and more efficient technologies for energy supply is becoming more and more essential.[1]

Fuel cell based mCHP is one alternative technology with significant future potential for wide implementation. After a slow start caused by the early stage of technology development and consequently by the initial high costs of fuel cell, the world market of fuel cell is now growing steadily.

According to the Fuel Cell Europe organization, Europe is not ready for the commercial introduction of fuel cells at the same time as other regions of the world such as North America and Japan. [2] However, Europe is making significant progresses in mainly derived from a strong R&D investment strategy and also by the multi-goal approach of R&D investment in strategic technologies: enhancing security of energy supply, reducing green house gas emissions and strengthening European innovation and growth.[3]

In this scope, and in order to get a better view of the current European landscape in terms of available technologies and their potential contribution for the future of the region, it is important to assess future trends, risks and opportunities in the short, medium and long term, to identify potential practical and operational recommendations and implementation strategies, and to identify appropriate initiatives or actions that should be taken in time to enable sustained growth towards already established goals.[1]

The main objective of the WP6 report is to identify and organize key aspects related to the introduction of residential fuel cell based mCHP on the energy market in three countries in Europe (Denmark, France and Portugal), and based on the analysis of the data through PESTLE and SWOT frameworks, reveal insights about the current situation in the field and the possible future prospects of the technology within the geographical context of the work.

Therefore, the more detailed objectives of this report are:

- To construct a comparative analysis between the three National Cases considered by the FC4Home project (in Denmark, France and Portugal), taking into account relevant factors that affect directly the introduction of the residential fuel cell based mCHP on the energy market, organized into six main fields (Political, Economical, Social, Technological, Legislative, Environmental) – PESTLE framework;
- Identify the strengths, weaknesses, opportunities and threats of the factors at both national and European levels;
- Discuss how strengths can contribute to take advantage of opportunities and how weaknesses can be minimized or eliminated by focusing on strengths and opportunities;
- Identify the risks of not inaction.

2. Introduction

According European Hydrogen and Fuel Cell projects report, energy is the main determinant of economic growth and deficiencies on energy sector, and can have a direct impact on EU economic growth, stability and well being of Europe's citizens.[4]

Nowadays in Europe, the energy situation is characterized by the gradual liberalization of the market, and by an ongoing hardening of environmental protection measures including reduction of CO2 emissions. Regarding the security of supply and mitigation of climate change effects, research and development actions are seen as key for the development of competitive and sustainable energy technologies.[1],[5]

The increase of electricity prices and the pressing need for renewable energy sources led to an increased interest of the industrial sector to the micro combined heat and power (mCHP) technology. The ability to produce both heat and electricity has opened new alternative paths towards sustainable growth and also and market opportunities for the involved stakeholders.[6]

In order to give an integrated overview of current results of the FC4Home project the present report is organized as follows:

Section 4	Contextual link of the contents of the report with results from previous work packages of the project.
Section 5	Description of methodological analysis applied for the results.
Section 6	Main findings of PESTLE framework classified based on different impacts.
Section 7	Strengths, weaknesses, opportunities and threats identified for each country based on PESTLE findings.
Section 8	Main conclusions of the work.

3. Contribution of the previous work packages of the FC4Home project

In recent years the European Union has established ambitious goals in terms of energy savings, efficiency increase, customer proximity, and flexibility in terms of scale and operation, and environmental issues. In this way, the basis for a possible promotion of fuel cell powered (micro)-CHP is entrenched in its potential contribution to the three main objectives of European energy policy: sustainability, security of future energy supply and competitiveness. The impact of a positive contribution towards the three above head mentioned objectives of European energy policy depends on the type of fuel used, the efficiency and specific technological attributes of a fuel cell, type of ownership structures, and support schemes as well. A more detailed description of the European Legislation and the potential contribution of fuel cell in energy policies can be found on the WP1 report of the current project.[7]

Due to the characteristics of the technology, fuel cells show specific advantages related to operation and modular capacity sizes. Fuel cells can use different types of fuel, such as natural gas, biogas and hydrogen, and can be installed in arrays yielding flexible capacity at different scales. The flexibility in fuel use may lead to a greater diversification of the European Union primary energy sources. On the same way, depending on the type of fuel used, fuel cells powered mCHP may also contribute to the reduction of pollutants emissions improving key sustainability performance indicators. Finally, but not less important is the change from centralized to decentralized electricity production scheme that fuel cells can promote. As mentioned before in regard to support schemes, several types have been used in different countries in Europe, which differ in their approach to the market, financial levels and impact of implementation (see **FIGURE 1**).

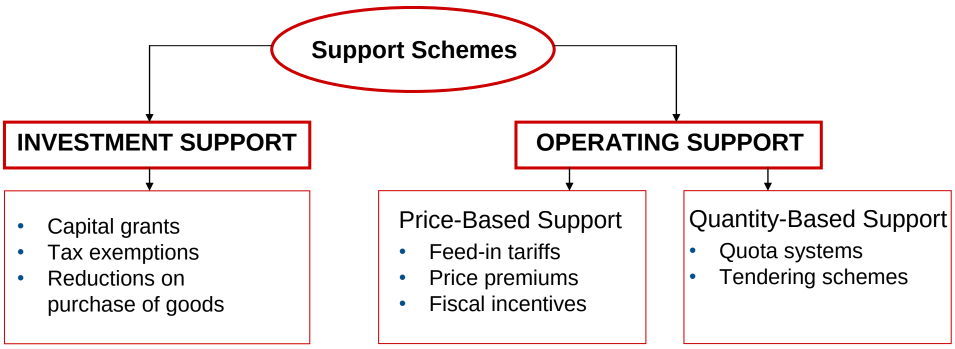

FIGURE 1. Overview of analyzed European support schemes (source: WP1 report).

As can be observed, support schemes can be differentiated mainly by its focus on investment support and operating support. Investment support is provided upfront for the raise of generation capacity and is frequentely adopted to stimulate technologies in early development stages or to finance demonstration projects for launching new technologies. These kind of supports include capital grants, tax exemptions and reductions on purchase of goods. As for operating support, two sub-categories are to be distinguished: price-based support and quantity-based support. The diference between these two support categories lies in whether the regulator fixes the price or the quantity.

Price-based support schemes encompasses feed-in-tarif, price premiuns and fiscal incentives; quatity-based support encompasses quota systems and tendering schemes.

Finally, there is also as a support scheme the net metering that is a indirect way of remunerating generation from a distributed generation unit at a consumer's place. The consumption is reduced by the own generation.

Traditionally, feed-in tariffs have constitued the predominant support scheme for the promotion of renewable electricity in the European Union. However, several kinds of support schemes can be adopted for stimulating technological development.

The choice of support scheme has to take into account the project developer's decision to invest in a new technology depending on the expected return of the investment and thereby the costs and risks of the investment. In the early stages of the development of a technology the technological risks and associated costs are very high (**FIGURE 2**). In this case a high degree of investment certainty might encourage investments in the technology. As the technology matures the technological risk decreases and operational support schemes may be considered. In this stage it is the regulatory risk that is dominating. Finally, when the technology has reached the level of maturity that corresponds to competitiveness it will be market risk that dominates the technology.

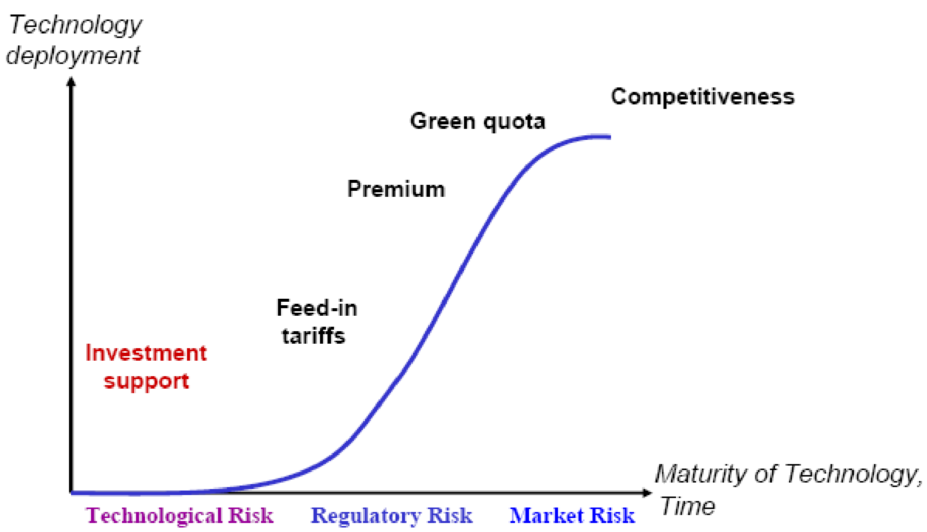

FIGURE 2: Support schemes and maturity of technology (source: WP1 report).

The above mentioned analysis is mainly based on the point of view of a small private investor such as a household, and from that point of view fuel cell mCHP is located in the lower left corner with high technological risk pointing in the direction of investment support. However, it can be easily suggested another kind of investor with higher demand for rate of return and more capital funds available. For this kind of investor it would be more relevant to introduce a price premium.

According to the focus group interviews and as described in WP2 report, a good combination of investments support and some type of operational support will be the right way to induce investments in fuel cell based mCHP in Denmark and France (**TABLE 1**). First of all the upfront investment support will reduce the investment costs and operational support will play an important role when taking the perspective of the system in order to add to grid balancing.

TABLE 1: Support schemes and background motivation (source: WP2 report)

	Denmark	France	Portugal
Support schemes	Upfront investment support plus premium on market price.	Upfront investment, e.g. capital allowance, plus Operation support, e.g. premium on auto-consumption or fixed feed-in tariff;.	Premium on top of the market price; Low tax rate.
Motivations for this support scheme	Reducing user's initial investment costs; System perspective: grid balancing.	Reducing user's investment costs; Compensating maintenance costs.	Most attractive to companies, reduces risk; Reflecting market prices.

Regarding ownership structures there are also two perspectives: "consumer plug and play" and "company control" and according focus group interviews on WP2 report the direction that for Denmark both arrangements are relevant whereas in France the "consumer plug and play" solution seems to be the most realistic and in Portugal it is the "company control" model that is the most probable (see **TABLE 2**).

TABLE 2: Ownership structures and background motivation (source: WP2 report)

	Denmark	France	Portugal
Ownership Structures	Owned by households; Operated by users or an external service provider, e.g. gas supplier or grid company.	Owned and operated by households.	Owned by service providers (equipment manufacturers or utilities) let to households.
Background of this Ownership Structures	Some users expected as very active part in the energy system; Other users expected to be oriented towards minimising efforts and maximising gains.	Path dependency: installations traditionally owned by households; More active users expected in the future energy system; Energy companies reluctant to be owners.	Reducing households' transaction and maintenance costs; Reducing service providers' financial risk.

In Denmark this is motivated by the assumption that some users are "homo oecologicus activus", i.e. consumers who consider themselves as active promoters of environmental protection and others are "homo oeconomicus", i.e. users who, given the information at hand, are aiming to maximize their own economic benefits and minimizing resources (Huber et.al. 2010). In France installations have traditionally been owned by households and the indication is therefore a result of path dependency. In general the focus group in Portugal is the one among the three countries being most skeptics towards fuel cell based mCHP and therefore expect the ownership structure with the least transaction and maintenance costs for the households and the least risk for the service providers.

On the WP4 and on the WP5 of this project a private economic analysis was done in order to determine which support schemes are the most optimal to apply. It was defined a range of scenarios depending on ownership arrangement, control strategy and support scheme. When it comes to ownership arrangements, the distinction is made between consumer plug and play on the one hand and company control on the other hand. The control strategy can either be thermal control or virtual power plant control (VPP). Furthermore, the thermal control strategies are divided into two: one with a single constant electricity price and one where peak periods are taken into account. The motivation for including this possibility is the technology already in place in France and Portugal giving the consumers the opportunity to choose a price scheme based on a peak and off-peak tariff (see **FIGURE 3**).

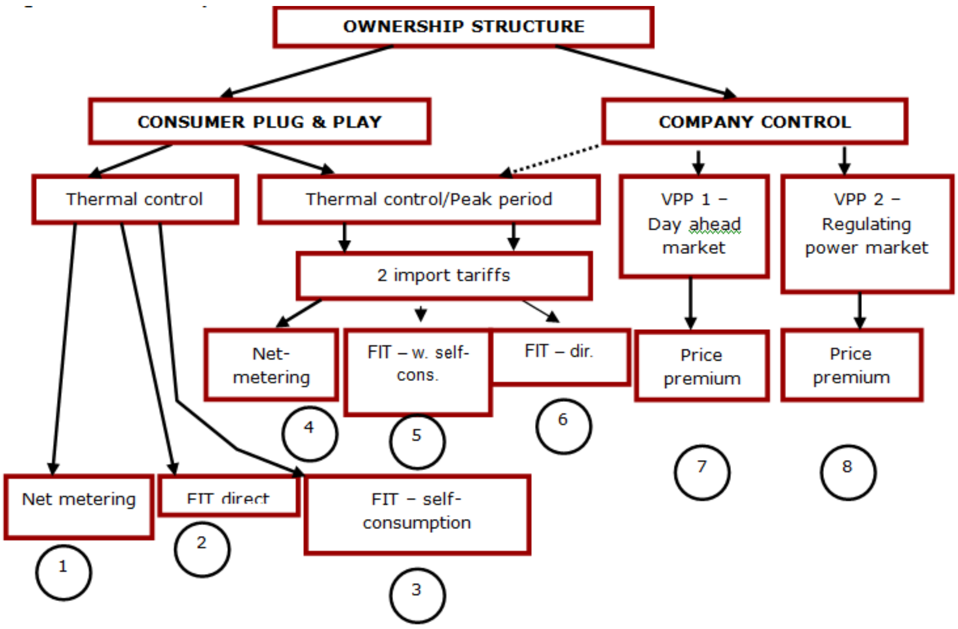

FIGURE 3: Ownership structure, operational strategies and support schemes (source: WP4 report).

A more detailed description of the different types of ownership structures can be found on the WP4 report of the project.

In order to analyze the need for financial support for promoting the diffusion of mCHP in individual households from a private economic perspective, a model was proposed (WP4): Support Schemes for Fuel Cells (SS4FC). Its main objective is thereby to give an indication of the required level of investment or price support in order to make the technology economically viable and possibly an argument for political justifiability. The aim of the SS4FC model is thus to assess which support levels have to be granted under different promotion schemes and ownership arrangements.

4. Methodology

Based on the findings of the previous work packages, the present analysis takes a PESTLE framework (Political, Economical, Social, Technological, Legislative and Environmental) as a way to organize aspects for the SWOT analysis (Strengths, Weaknesses, Opportunities and Threats). The PESTLE framework was complemented with an impact analysis on PESTLE findings, in order to add clarity and insightfulness to the selection of most relevant aspects to be considered for the SWOT framework. Criteria like time horizon, extent of impacts, relevancy, and connection with the main objectives of this work were applied to the results of the PESTLE.

The PESTLE framework was developed based on public information and reports available from partners of the FC4Home project. Political factors considered government policies relating to the technology, public support and existing public R&D funding programs. Economic aspects were related to changes in the economy such as GDP growth, specific market characteristics and technology costs trends, and also considered the current situation in Europe in regard of the financial markets and their impacts in local/European economies. Social factors were focused on consumer awareness and consciousness; technological factors were related to characteristics of the fuel cell technology, the influence of the competing technologies and current R&D activity levels; legislative aspects referred relevant national laws and regulations; environmental factors include European environmental policies and legislation, as well as relevant environmental impacts. Results from the PESTLE and the integrated impact analysis were used to perform a SWOT analysis.

The SWOT analysis was developed starting with a national perspective for the three countries in analysis. Taking into consideration the nature and form of the findings of previous work packages as well as the findings within the context of this report, the SWOT analysis was structured in two main sections: One comprising the strengths and weaknesses, the other focusing on opportunities and threats. This organization was used in order to enable a better integration of common factors into the discussion at National and European level, and to lead to a better understanding of the key factors involved.

5. PESTLE framework

As mentioned before, PESTLE framework findings were reinforced with the addition of an impact analysis which considered each of the aspects related to the findings from the PESTLE. As a way to bring clarity to the evaluation of each of these aspects, a set of descriptors for both degree of impact and tendency to change in the future was presented (see **TABLE 3**). The measure of the degree of impact is not an absolute one, but a relative one based on the observed relevance of the aspect in the data gathered for the analysis. The tendency to change in the future is also a result of the observation of trends, current status and change of key elements related to the aspect.

TABLE 3: Set of descriptors used in the extended PESTLE framework for the degree of impact and tendency to change in the future.

Symbol	Interpretation for the analysis
+	Low impact
++	Medium impact
+++	High impact
>	The aspect presents a tendency to increase its impact in the future
<	The aspect presents a tendency to decrease its impact in the future
=	The aspect in analysis tends to keep its current impact in the future
S	Presents impact in the short-term
M	Presents impact in the mid-term
L	Presents impact in the long-term

Results of the modified PESTLE are shown in **TABLE 4**. The lists of relevant aspects are organized from higher to lower impact.

TABLE 4: Summarized results from the modified PESTLE framework.

PESTLE Analysis				
	Impact	**Trend**	**Time horizon of the expected impact**	**Relevance**
Political	Consideration of European energy policies	>	S/M	+++
	National support and ownership structures	>	S/M	+++
	Support for R&D investments and funding projects	>	M/L	+++
	Government organization and political uncertainty	<	S	++
	Inter-country relationships/attitudes and geopolitical issues	=	S/M/L	++
	Importance of stakeholders needs/demands	>	S/M/L	++
	Existence of National market lobbying/pressure groups	<	S/M	+
	Impact of Bureaucratic aspects	<	S	+
	Effectiveness of campaigns and dissemination activities	>	S	+
Economical	Financial crisis	<	S/M	+++
	Future trends on the energy markets	>	M	+++
	Investment costs of fuel cell technology at domestic level	<	M	+++
	Trends in electricity and natural gas prices and source of natural gas	>	M/L	+++
	Liberalization process of the electricity market	<	S	++
	Decentralized/centralized production of energy	>	S/M	++
	Existence/development of niche markets	>	S/M/L	+
Social	Effectiveness of available information on consumer awareness	>	S/M/L	+++
	Ownership schemes and historical trends	>	S/M/L	+++
	Geographical and demographic National profiles	<	S/M	++
Technological	Competition from existing technologies	>	S/M/L	+++
	Technology access, licensing, patents	<	S/M/L	+++
	Flexibility, variety and maturity of fuel cell technologies	>	S/M/L	+++
	Operational strategies	>	S/M	++
	Research funding availability	>	M/L	++
	Historical trends	<	S/M	++
Legislative	European and National legislation	>	S/M/L	+++
	Public, grants and incentives	>	S/M	+++
	Competitive regulations	=	S/M/L	++
	Consumer protection framework	>	S/M/L	+
Environmental	Environmental goals	>	S/M	+++
	Environmental impacts	>	M/L	++
	GHG emissions	>	S/M/L	++
	Stakeholder commitment with environmental values	>	M/L	+

6. SWOT Analysis

6.1. Strengths and weaknesses

6.1.1. Political aspects

Consideration of European energy policies

The possibility of promoting fuel cell technology powered mCHP in Europe is originated based on the potential contribution of the technology in the three main marks of the European energy policy: *sustainability*, *security of supply* and *competitiveness.*[8] Fuel cell based mCHP can contribute to the achievement of these three objectives in the sense that it can be used as a distributed power generation unit at different scales and using different fuels.[7] These aspects are described on the WP1 report:

- The contribution on *sustainability* depends on the type of fuel used that may reduce the pollutants and greenhouse gas emissions and on the improvement of energy saving and efficiency gains achieved by combined heat and power;
- The flexibility of fuel cell on the capacity sizes, usage of different types of fuel (natural gas, biogas or even hydrogen) and because are located in close proximity which avoided network losses may lead to a strong diversification enhancing *security of supply*;
- When it regards the *competitiveness*, the diffusion of fuel cells reinforces the trend towards decentralized electricity supply that may lead to a stimulation of competition in electricity markets.

Objectives that promote sustainability, such as greenhouse gas (GHG) emissions reduction, increase in the renewable energy supply and promotion of energy consumption efficiency, are indicated as the main driving forces required for development in the direction of the implementation of decentralized and renewable energy supply systems.[9],[10]

National support and ownership structures

The structure of national schemes is largely dependent of the availability of financial supports from the European funds within established or new European promotion frameworks.[11] The predominant support scheme in the European Union for the promotion of renewable electricity is based on the subsidy of feed-in tariffs. Following European trend, Denmark, France and Portugal have such schemes already implemented.[7] Denmark promotes the utilization of renewable energies based also in additional subsidies and loan guarantees, while France and Portugal utilize fiscal regulation.[7],[12] Support schemes for the promotion of residential fuel cell based mCHP, in Denmark, France and Portugal are described on the WP1 final report of this project.[7] It is important to refer that the feed-in tariff support in Portugal is only valid for fuel cells that use renewable sources as fuel.[7]

In addition to the operational supports, the Danish government also includes an investment support for domestic fuel cell units in order to reduce the investment costs for the consumers.(13) The fuel cell mCHP technology is still considered to be in an early stage of development thus still considered as owning technological risk to some extent. In this stage, the Governments need to recognised that fuel cells are too expensive and there's a need to implement supports based on investment and operation in order diminish this impact on investors and consumers.(14) When it comes to Governmental strategies for the energy sector, Denmark and France show different strategies for the promotion of fuel cells compared with Portugal. This is also due to leadership aspects that the different countries show in the technology field. The hydrogen and fuel cell technologies are considered by the Danish government as key elements of its strategy for the future of the energy sector in the country.(15) In France, the National Strategy for Energy Research also identified fuel cells as one of the main technologies that should be promoted and developed.(16) The Portuguese government has been applying efforts in transforming its energy mix into a more renewable one by investing in existing renewable energy sources like wind and hydropower. Considerable effort has also being applied in the field of energy efficiency both at production and consumption levels. The promotion on the development of fuel cell technology is not expected in the next years.(17)

Regarding the ownership structures in Denmark, the residential fuel cell can either be owned by the household itself or a large company such as energy companies and the support schemes found the most appropriate for promoting residential fuel cells is an investment support and price premium. In France, the fuel cell is expected to be owned and operated by household. The support schemes would be upfront investment, e.g. capital allowance, plus operation support, e.g. premium on auto-consumption or fixed feed-in tariff. In Portugal, the fuel cell is expected to be owned and run by a service provider supported by a premium on top of the market price maybe in combination with low tax rate.(45)

Overall with the results of WP4 it was found that some technological development within FC-based mCHP is necessary in order to make the technology truly interesting as the expected prices the next 5-10 years are too high. However, the necessary support levels found in the analyses are not monstrous compared to the initial support levels for e.g. PV's in Germany. Especially considering the opportunity for biogas in gas based FC's makes the found support levels promising.

Assuming that FC's are to be implemented and according the conclusion of the WP4 report the best solution for the three countries are:

- Denmark: installing FC based micro CHP in households with high electricity consumption due to the high end consumer electricity price in Denmark.
- France: As the natural gas price in France are quite low (compared to Denmark and Portugal) a FC run as a virtual power plant (VPP) on the spot market seems to be the best solution in France.
- Portugal: The electricity spot price in Portugal is relatively high, resulting in results similar to those obtained for France - a FC run as a VPP on the spot market might be also the best solution.

For France and Portugal we find that the support mechanism based on self consumption in combination with feed in tariff is not a good solution (see results from WP 4 report).

R&D investment and funding projects

In the past 10 years, when considering R&D energy investments volume, it can be said that Europe has been losing leadership in this area for Japan and United states, and that in the last decades the investment seems to be insufficient.(1) In that regard, several initiatives have been implemented like the increase in the budget for the Framework Programmes, the development of sub programmes like the HY-CO program and other focused on specific technological niches like EUREKA umbrella and EUROSTARS.(3) the situation at national level is also different from country to country, with countries that invest different percentages of GDP in R&D programs. Among other, Denmark and France are also on the top of the lists in R&D investment amounts.(19) Denmark aims at doubling public funds for energy technology research and demonstration in some focus areas such as hydrogen and fuel cells, wind turbines and biofuels. Nowadays 33% of the Danish public's funds for development of energy technology are spent on hydrogen and fuel cells.(20) One of the key elements in the current Danish Energy Strategy is to improve energy efficiency and give more economic incentives for the consumers to promote a change in their attitude and choices.(21) These initiatives situate Denmark in a strong position within the European R&D framework, especially in fuel cells field, reinforcing its competitive advantage in the sector.(21)

The situation in France is different. France's energy R&D budget has been considering an important number of projects related to nuclear power and less focus on new technologies, although fuel cells is a topic with relative relevance within the R&D sector, which can be considered as a positive sign for the development of the mCHP technology based on fuel cells.(22)

Public R&D budget per unit of GDP for the energy sector is smaller than in Denmark or France, although the country already demonstrate its will to overcome the current situation and fill the gap between its own R&D budget and the European average.(23),(24) The main obstacle observed in the country for a lean development of the sector is the lack of organization/collaboration between the private sector, the academic sector and the public funding resources, which clearly shows the lack of an integrated strategy and leadership on the side of the government.(25) In that regard, the availability of demonstration projects of national cases of each country (Denmark, France and Portugal) could be seen as drivers for the promotion of awareness and a better understanding of the opportunities of fuel cell mCHP in the energy sector.(8)

Other political aspects

Some of the European countries are experiencing financial and political instabilities which drive reductions in budgets for the public sector and uncertainty in the public sector investment rates. . Portugal for example, faces a volatile political scene after the collapse of the Social Party due to financial issues, which yielded a change in government. These changes may result in a shift direction for policies development and short and midterm strategies, clearly affecting the energetic sector and the consideration of the introduction of new technologies. In Denmark are also expected changes on the government. The centre-right minority coalition governed by Liberal-Conservative parties have losing strengths and it is expect that the left-wing opposition will win the next election in the final of 2011 with accentuated reforms on the policies coming, although the country has a historic tradition of commitment with long-term objectives. In France the centre-right administration, dominated by members of the Union pour un Movement Populaire also seems to losing ground against the opposition.(26),(27) Tension and sources of risk can be seen not only within Europe, but also coming from countries that provide oil and gas. Situations like the interruption of gas supply from Russia and the increasing political instability in the Middle Orient are examples of such situations.(27),(28) There is a difference between the geopolitics of conventional energy (oil, natural gas and coal) and the geopolitics for renewable energies. The current economic crisis has brought an increase on the energy prices and also a slowing down in the rate of investment in renewable energy, although in a geopolitical perspective the countries that invest in renewable energy sources and technology may become the dominant geopolitical players tomorrow like it can be seen in the BRIC countries.(29)

6.1.2. Economical aspects

Financial crisis

Nowadays, the Portuguese economy is expected to contract in 2011 and most of 2012, being the only country in Europe which should still be in recession this year. Budget deficit reduction is underway and will proceed in the context of a financial assistance programme agreed with the European Union and the International Monetary Fund (IMF).(31)(32) Even being one of the European countries in a better and stable financial situation, Denmark is also experiencing the consequences of the financial crisis. The Danish economy fell back into recession at the start of 2011. Real GDP contracted by 0.5% quarter in the first quarter of 2011, following a 0.2% contraction in the final quarter of 2010. France's economy continues growing when if regards the curve of real GDP growth. The French government also felt necessity to apply austerity measures to face the economic difficulties experienced in Europe.(31),(33)

Despite the growing trend of the gross domestic expenditure on R&D (**TABLE 5**), the financial uncertainty may lead to cuts on the supports and on R&D investments rates.

TABLE 5: Gross domestic expenditure on R&D, % of GDP (source: OECD (2011))

GEO/TIME	2003	2004	2005	2006	2007	2008	2009
European Union (27 countries)	1,76	1,73	1,74	1,77	1,77	1,84	
Denmark	2,58	2,48	2,46	2,48	2,58	2,87	3,02
France	2,17	2,15	2,10	2,10	2,07	2,11	2,21
Portugal	0,71	0,75	0,78	0,99	1,17	1,50	1,66

Future strategies on the European energy markets

The energy situation, in Europe, is characterized by a gradual liberalization of the sector, and hardening of environmental conservation measures.(34) Denmark has increased its use of biomass in CHP plants, and set ambitious targets for increased use of biomass in electricity production, district heating, and individual space heating. The share of wind energy in electricity production has also grown significantly in Denmark, and was 20% of electricity supply in 2007.(21) Portugal has a strong dependence on imports of oil, natural gas and coal which maintains around 82% of total primary energy consumption in the last ten years.(18) Several reforms were also implemented in the wholesale Portuguese electricity market with the implementation of the future market platform (OMIP) related to the Iberian electricity market.(12) Both of these changes represent good progress over a short period of time. These could increases the attractiveness of investing in generation (conventional and non-conventional) in Portugal, strengthens security of supply; increases competition in the domestic market, and will eventually allow Portuguese market participants wider access to other European markets.(12) France is also relatively well positioned achieving a good progress in the electricity market sector since the last IEA review, including market openness, reduction of state control in energy generation assets, as well as in improved generation transparency. Nevertheless the country will have to implement measures to enhance competition in the generation and retail sectors and is developing a strategic vision for electricity network infrastructures, taking into account key emerging trends such as demand-side management and the increasing of renewable-based and distributed generation, making full use of the potential of smart metering and smart grid capabilities.(16)

Other economical aspects

The high investment cost related to fuel cell unit constitutes an important barrier for the wide introduction of the technology into the domestic market in all three countries analyzed.(7) Additionally, electricity and gas prices are also presenting some resistance to support the introduction of new fuel cell technology.

6.1.3. Social aspects

Effectiveness of available information on consumer awareness

Consumer awareness is considered as one of the most important aspects to be taken into account when introducing new technologies in the domestic energy market. Lack of consumer interest and awareness, and perceptions of higher prices can influence negatively the will o change or invest in new equipment or economic relationship with utilities. There is a reported unawareness about the economical and environmental benefits of some technologies among prospective customers and consumers.(12) Portuguese consumers consider can e described as costs oriented and prefer to invest in cheaper technologies as compared to more environmental friendly technologies with a higher price.(24) In Denmark and in France, the citizen’s awareness share widespread concern for climate change and for energy sources, which reflects relative willingness to pay high prices for alternative and environmental resources.[7]

6.1.4. Technological aspects

Competition from existing technologies

The market for mCHP is growing, but high investment costs and some efficiency issues still act as barriers for a wide implementation. Moreover, mCHP is also competing against other technologies for the same funding sources in many countries.[35]

France for example, since 2007, accounts with approximately 80% of electricity production using nuclear power where 40% of primary energy supply. When it comes to renewable sources, France shares around 7% of total energy supply and has made several efforts to promote renewable with lower taxation for biofuels, investment grants and incentives, FIT (feed-in tariffs), tax credits or reductions for purchase renewable equipment.[16]

In Denmark, there has been considerable growth in the sale of heat pumps to private households. At the same time, wind power energy is also growing providing 18.9% of electricity production and 24.1% of generation capacity in Denmark in 2008, Denmark was a pioneer in developing commercial wind power during the 1970s, and today almost half of the wind turbines around the world are produced by Danish manufacturers.[45]

Portugal is also moving towards it renewable energies namely solar, hydro and wind. In the latest years Portugal constructs one of the largest photovoltaic power stations of the world that expects to be capable to generate 93 GWh of electrical energy annually. When it comes hydro power Portugal is one of the European Union countries with the highest exploitable hydropower potential. Hydropower is clearly a priority and one of national energy policy's principal commitments, with the objective of exceeding an installed rated power of 7000 MW by 2020. Finally, in March 2007, there was 1,874 MW of wind power generating capacity installed in Portugal, with another 908 MW under construction.

Technology access, licensing, patents

Distribution of patents and technology licences can be used as an indicatior for the level of technology development in certain areas. In the case of fuel cell technology in Europe, Germany leads the way with 360 granted patents until 2010, while France reaches with 55 and Denmark with 16. On the other way Portugal has not any granted patents when it comes to fuel cells. [fuel cell today]

The licensing procedures are considered as a barrier on the commercialization of new technologies. In Portugal, for example, the license procedure for renewable energies and some decentralized technologies are complex and lengthy.[6]

Flexibility, variety and maturity of fuel cell technologies

Advantages of the fuel cell technology are wide and numerous when compared with conventional power generation, like for example high efficiency, low chemicals utilization, low acoustic impact, low thermal emissions, technological reliability and low maintenance due to the absence of moving parts. The cogeneration and the modular capacity sizes characteristics are strengths of the technology that may contribute to the goals of European energy policy.

6.1.5. Legislative aspects

European and national legislation

At a European level, the promotion of the generation of electricity based on renewable energy sources was adopted by the Directive 2001/77/EC, which was updated by the new Directive 2009/28/EC. The promotion of cogeneration based on heat demand was created with Directive 2004/8/EC. The objective of these Directives is to support the member states when choosing the type of support scheme to promote different technologies at a national level. In Denmark, the promotion of combined heat and power technologies is supported by Danish Electricity Act to implement liberalization of the Danish electricity market. The promotion of sustainable heat supply is supported by Act of Heat Supply with the objecting of promoting the most socio-economically efficient and environmentally friendly use of energy.(37) In France, activities against climate change are a priority of French energy policy. Since 2007, The *Granelle de l'Environment* reinforced the development of district heating. In France the first support in feed-in tariffs for CHP unties was introduced in 1997 without restrictions of power inputs. In 2001, French regulation on CHP production fixed the conditions new feed-in tariff less favorable than previous regulation with restricted conditions for power plants below 12 MW. The order of 13 March 2002 fixed the purchase conditions of electricity produced by installations below 36 kVA. However, since 2007, this Granelle de l'Environment has put the emphasis on the development of biomass and the reinforcement of district heating but no concrete incentive has been put into place in favor of cogeneration.(37) Portugal's legislation on CHP is included in renewable energy policies. Since 2001, fixed and feed-in tariff were granted, but only for technologies that use renewable energy as source. Since2009 a regime establishes a maximum power connected to the grid is 12MW.(23)

6.1.6. Environmental aspects

Environmental goals

In January 2008, the European Commission proposed the 20-20-20 targets.(27) A comprehensive package of proposals on energy efficiency and tackling on climate change was proposed, aiming to put Europe in a leading position in terms of legislative measures preventing global warming. This climate and energy package creates pressure on socioeconomic stakeholders to improve energy efficiency both at generation and consumption levels.(27)

According the European Union Strategic Energy Technology plan (SET plan), the target for the residential sector is set to reduce average household energy consumption by ~30% by 2050, and tend towards zero emission houses by 2050. This strategy involves changes on the households' behaviour reducing energy waste and improving energy efficiency and on new technology improvement. It is expected for homes to tend towards self sustainability and to be able to produce a substantial share (more than 80%) of the total energy consumed by 2050. The possibility that houses may also store electricity and exchange it with smart power grids is an interesting picture for Europe, with a potential of reduction in 50% of current residential CO2 emissions by 2050.[(38),(39)] Over the last decade, Denmark, France and Portugal have made important progresses in protecting the environment, when it comes investing in sustainability and environmental energetic strategies which show political will, but also traction together with social actors and the private sector.[(12),(16),(20)]

Fuels cells are generally believed to be an environmental friendly technology. The environmental impacts of fuel cell use depend upon the source of the hydrogen rich fuel used. By using pure hydrogen, fuel cells have no emissions except water but, are rarely used due to problems with storage and transportation.[(42)] Additional benefits include non or almost non emissions of criteria pollutants (NOx, SOx, CO, and hydrocarbons).[(41)]

A resume of the strengths and weaknesses of each PESTLE section can be found on the table below (see TABLE 6).

TABLE 6: Resume of strengths and weaknesses of residential fuel cell based mCHP.

	Strengths	Weaknesses
Denmark	Fuel cell development side by side with European energy policies and environmental goals; Positive promotion of fuel cell and CHP technology; Support on the investment and operating support in fuel cell and mCHP Strong position in expertise and know-how in sustainable energy technologies; High R&D investments and budget for fuel cell and mCHP projects; Rich mix of decentralized and centralized energy market; Increased social acceptance; Efficient flexibility and variety of fuel cell.	Political uncertainty; Lack of specific legislation.
France	Fuel cell development side by side with European energy policies and environmental goals; Good national promotion of fuel cell and CHP technology; Good support in FIT; High R&D investments and budget for fuel cell and mCHP projects; Flexibility and variety of fuel cell.	Lack on the investment support Political uncertain; High investment costs for the investor; Lack on specific legislation.
Portugal	Good promotion on feed-in tariff but only for technologies that use renewable sources as fuel;	Lack on the investment support and feed-in tariff for mCHP using natural gas as source; Political and economic instability and uncertainty; Lack on the policy support and specific legislation; Centralized market; High investment costs for investment; Low consumer awareness.

6.2. Opportunities and threats

6.2.1. Political and legislative aspects

A common understanding and awareness about the importance and opportunities related to the utilization of fuel cell as an option of energy source technology have been growing in the latest years. In fact, fuel cells can contribute to the future decentralized generation structure and to the sustainability and security of supply of the energetic market.

The Danish Energy Strategy 2025 sets out the government's long-term goal of balancing the objectives of environment, competition, security of supply and business potentials with the objective of unlock the full benefits of liberalization of energy policy sand market. An important element of this objective is the development of a well-functioning electricity market.(7) Denmark is also investing largely in campaigns for the utilization of the small privately used heat pumps and in R&D for renewable energies but also for fuel cell development.(7) In France the energy policy seeks to achieve a balance between the environmentally responsible production of energy and its consumption, the growth and competitiveness of the economy, and secure and competitively priced energy and infrastructure. The National Strategy for Energy Research aims at increased energy security and combating climate change and identified the following focal points for research.(7),(37) The French government also creates several groups with governmental organizations, and public and private energy companies to work together on the development of fuel cell as for example, the PACO Network (French technological network on fuel cells).(7) The Portuguese government has encouraged the use of renewable technologies promoting renewable through FIT, grants and investment incentives. According to the Portuguese Renewable Energy Association (APREN), Portugal has surpassed its target from 2010, 39% in terms of generation of electricity by renewable energy.(35) In 2007 electricity from renewable resources was 39,7%. The objective is achieving 50 % of electricity production from renewable resources by 2012. Investment is being focused in already existing technologies with no signs of including new technologies. (12),(18),(35)

In conclusions, at a political and legislative level Denmark and France seems that are creating more opportunities to the introduction of fuel cells as a viable option. In other hand, in Portugal the strong promotion on renewable energies namely solar, wind and hydropower and the long-term nature of the investment could act as a barrier for the introduction of mCHP based on fuel cell technology.

6.2.2. Economical aspects

Liberalization of the electric energy markets will impose a series of different challenges to the different stakeholders in each country. In spite of the increased use of market mechanisms as policy instruments the lack of a strong policy backup can lead to instability and unfairness both at the utility and end-consumer levels.(3) Together with policy development, support schemes and the liberalization of the energetic markets play an important role and a good opportunity for the introduction of new technologies. Due to current recession in Portugal and to the current European crisis is perceptible the financial difficulties for the implementation of new fiscal incentives outside the already implemented frameworks. At the same time, the current situation is characterized by an enormous heterogeneity in energy investments, whereby each country has its own technology R&D objectives. This divergences and dispersion on the investment targets may cause risks of insufficient resource allocation resulting in projects with little critical mass as well as synergy losses. At a time when Europe needs to invest largely, a better coordination and cooperation between the countries is essential.(12) The absence of clear strategies in the fields of competition in the generation and retail sectors can be seen as a threat when it comes to the development of a strong market with equal opportunities for the stakeholders.(18) Price tags and introductory prices are still seen as natural barriers for consumer acceptance and fast propagation of technology among utilities. (18)

6.2.3. Social aspects

Social and cultural aspects have a significant influence on technological transition. Every day routines and habits, preferences and locked-in logics of consumption are important features that may constitute significant barriers to changes in technological systems such as predominantly fossil fuel based energy system. Education and better information for the consumers allied with technology as well as pricing incentives will help users monitor and modify their consumption. To accomplish these, a better interconnection between countries and/or markets is crucial to decrease barriers exchange of different levels of experience and awareness between stakeholders.(38),(7)

6.2.4. Technological aspects

In Europe, the energy sector has shown a slow pace in technology change.(43) Two main factors may help to understand this slow pace change in the energy sector: the low price of fossil fuels until the beginning of the decade and the market failure created by the difference between private costs faced by investors and social costs given the absence of a carbon price.(11),(35) The main technological breakthroughs nowadays are related to intelligent energy grids, low carbon emission technologies and diversified and decentralized storage solutions. The fuel cell based micro CHP can in the future be integrated and related to all these aspects. Nevertheless, its current early stage of development may be seen as a threat of development of the technology at a time when it is necessary to find alternatives for the energetic sector with low investments.(44)

The cogeneration and the modular capacity sizes characteristics are strengths of the technology that may contribute to the goals of European energy policy and can be seen as a good opportunity to take advantage when against whit competing technologies.

Current pressure on the energy sector can be seen as a driver for opportunity for technologies like the fuel cell mCHP, in the sense that it can be described as a efficient technology when compared to existing ones, a flexible technology when compared to centralized/low scalability generation systems. Competition with other technologies based on wind and solaris a threat, but asymmetry of needs within the European region may turn this aspect into an opportunity in market niches.(7)

6.2.5. Environmental aspects

Environmental sustainability is a global issue that requires an integrated solution at local level. The European region shows a strong awareness level of its citizens towards environmental problems. There is also a strong commitment among member states in regard to joint efforts for climate change impacts mitigation, renewable energy generation and energy security of supply. All these aspects are tightly related to technological development which is seen as a driver for opportunity for fuel cell technology. On the other side, wind and solar power generation technologies have also a strong momentum in Europe, mainly driven by already made public and private investment, relative simplicity of technology installation and operation, scalability and wide applicability in many different geographic contexts. Competition from these technological sectors is a threat for the short and midterm implementation of fuel cell technology in the domestic market. As in other aspects related to technology, different systems can be seen alone and competitors, but when integrated there can be opportunities for success, like the case of the utilization of fuel cells for the conversion stage of the storage of wind energy as hydrogen. Different geographic specificities can also play a role when selecting technologies and fuel cells have opportunities in decentralized generation systems or at small scale in regions of low solar or weak wind characteristics. Integration seems to be the right path to transform threats into opportunities in the case of fuel cell technology.

TABLE 7: Resume of opportunities and threats of residential fuel cell based mCHP.

	Opportunities	Threats
Denmark	European policies and environmental goals side by side with fuel cell and mCHP; National policies bet on fuel cell and mCHP; Good political and financial support on fuel cell and mCHP; Increased R&D funding for fuel cell projects; Flexibility and variety of fuel cell; Positive social acceptance.	Lack of specific regulations and laws for fuel cells.
France	European policies and environmental goals side by side with fuel cell and mCHP; Increased R&D funding for fuel cell projects; Flexibility and variety of fuel cell technology; Strong public awareness on positive impacts of technology.	Lack on the support schemes namely investment supports; Lack of specific regulations and laws for fuel cells; Strong investment on nuclear energy.
Portugal	Fiscal benefits for acquisition of renewable energies or equipments using natural gas as a source; Strong bet on alternative and renewable energies;	Good promotions on wind, solar and hydro technologies against insufficient support for CHP technologies including fuel cell; Lack on investment support; Lack specific regulations and laws for fuel cells; Lack on the funding R&D fuel cell projects; Difficulties on getting access to monopolist Portuguese grid; Portuguese consumer reluctant with the technology.

7. Conclusions

The situation in Europe in regard to the energy sector is still far from showing a definite picture about the future. Current trends are still open to diverse technologies and economical aspects which also present local specificities in the different countries and are influenced by external factors outside the European region. Nevertheless, common European goals and synergies within the member states, as well as pressure from financial crisis are seen as drivers for integration and interaction between countries and systems, which is seen as a clear opportunity for development and growth of technologies like the fuel cell mCHP. Among the different aspects covered by the review of the PESTLE and the final organization of the SWOT analysis, some of them reveal themselves as recurrent and strongly related to others at different levels. A deep description and understanding of the complexity of the relations between these factors lies outside of the scope of this report and outside the capabilities of the frameworks applied for the analysis, both of them limited to and used only for the organization of relevant aspects and the identification of their basic patterns of interconnection and their impact regarding the mCHP fuel cell based field. However, three main aspects for analysis can be pointed out:

- Economic aspects have clearly a significant impact on the development of new technology and its introduction in the market. The financial crisis atmosphere is not only slowing down any existing efforts, but also playing a game-changing role when analyzing governments, utilities and private sector strategies for the short and mid terms. This impact is also relevant when considering the situation of the consumers in peripheral regions in Europe.
- Political and legislative aspects are second to none when considering relevancy for the introduction of new technologies in the energy sector for all the countries in analysis. Strategic relevance of the sector make it target for long-term objectives and investments that need to be assessed at political level and considered not only in regard to technological aspects, but also in the scope of social development and minimization of risk in the security of supply. In that regard, European goals and horizontal commitment to common objectives is seen as a positive influence for the development of changes within the energy sector and the consideration of new technologies and power production models like the fuel cell technology and a decentralized model respectively. Asymmetries between the different countries can be overcome by joining efforts under the same objectives.
- Social acceptance and environmental aspects share their horizontality in all countries as main concern and driver factor for the successful introduction of fuel cell technology in the mCHP sector. Social awareness, or the lack of it, is still seen as a barrier to the introduction of fuel cells in the domestic market.

As can be seen from the results, a considerable amount of relevant aspects are tied to long-term objectives and efforts, and also, to political and big scale economic investments. All of which suggest slow changes and strongly emphasise the relevance of strategy and vision aspects both at local and European levels.

From a political point of view, Denmark seems to have a good opportunity due to the advances in existing CHP policies and support schemes, including investment support for fuel cells. France is also showing an increase in the investment in sectors that consider fuel cell technology and mCHP sector, but the need of more efficient support schemes still persists. Portugal has a good promotion support for renewable energies, but is far behind on the specific promotion of fuel cell-based mCHP. Its strong focus on the promotion on existing technologies towards ambitious goals in terms of renewable energy generation may be hiding an outdated interest in new technologies.

A specific legislative framework seems to be generalizedly weak when considering the needs that the introduction of fuel cell base mCHP technology may demand. Inadequate regulations and/or outdated sets of laws can be considered as part of existing barriers against an agile and successful promotion of residential fuel cell based mCHP in the three countries. As in other fields, the development of a specific European legislation can be seen as a driver of traction for the transposition at national levels.

At an operational level, the existence of high levels of technological development can be seen as a critical key success factor. This is the case of Denmark and France, both with considerable technological advances in the field of fuel cells and related technologies. Portugal is still missing critical mass in the field and R&D activities are isolated efforts not belonging to an already identified need for action.

Although public awareness on benefits of the fuel cell technology still needs to be reinforced, Denmark and France appear to meet good conditions to the development of the residential fuel cell market. Portugal seems to be on its way to reach an acceptable level of public awareness, but there is still a long way to go even when considering the high expression of renewable power in its energy matrix.

The differences between the countries considered for this analysis are not only related to geographical aspects. Already implemented strategies and goals show clear differences in terms of execution of actions and results and difficulties towards the same kind of goals. The changing European scenario is not limited to the past and present situations, but also to the challenges and risk comprised for the future.

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